# 2.2 Houdini: Reconfigurable In-Tank Robot Deployment at Oak Ridge Gunite Tanks

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## Abstract

The Houdini remotely operated vehicle system was developed by Redzone Robotics, Inc., under contract to the Morgantown Energy Technology Center (METC) now known as the Federal Environmental Technology Center (FETC). Technical guidance was provided by the Office of Science and Technology Robotics Technology Development Program (RTDP) and by prospective users of the system at the Fernald Environmental Management Project (FEMP) and at the Oak Ridge National Laboratory (ORNL). Houdini is a remotely operated hydraulically driven vehicle with two skid-steer tracks. A Schilling Titan series hydraulic manipulator arm is mounted on the chassis to provide grasping and manipulation capabilities. The Houdini system is designed so that the approximately 4 feet wide by 4 feet long chassis can be folded like a parallelogram to a collapsed position narrow enough to fit though an access port into an underground storage tank. When a Titan II manipulator is used the system will easily fit through a 24 inch riser. When a Titan III manipulator is used then the access requirement increases by about two inches. The vehicle is also equipped with a plow blade that can be raised or lowered hydraulically. Since the vehicle weights approximately 1000 pounds and has a wide track it has little trouble gaining traction in most materials and is an effective mini bulldozer for in-tank operations. The Titan manipulators have a lift capacity of about 240 pounds and a reach of more than four feet. Two camera systems are on-board, one on the wrist and one on the chassis, each with lights, pan and tilt, and lens washing features.

The first Houdini system was completed in September of 1996 and delivered to ORNL for use in remediation of the Gunite and Associated Tanks (GAAT). A similar application has also been considered at the FEMP for sludge removal from the K-65 Silos. For use at ORNL the Houdini vehicle was integrated with a tether reel assembly for deployment and retraction into the tanks and a containment structure for storage of the vehicle when not operating in the tank. The tether reel and containment box are known as the Tether Management and Deployment System (TMADS). Glove ports were added to two opposite sides of the TMADS to allow access to the vehicle while

in containment for minor maintenance and decontamination. At ORNL a large steel platform has been built over the gunite tanks to support the waste retrieval system. The TMADS is supported by an I-beam structure mounted on the steel platform. An extension has been added to the TMADS to provide above platform access for bag in and bag out of tools and other equipment to be deployed with Houdini. A spray ring has been attached at the tank riser interface for decontamination of the Houdini with a high pressure wash. The entire Houdini system was installed at the ORNL Tanks Technology Cold Test Facility along with the remainder of the tank waste retrieval system (including a waste dislodging and conveyance system and Modified Light Duty Utility Arm). For eight months these systems were operated as independent systems and as integrated systems in a qualification test program to prepare for deployment in the GAAT Treatability Study and GAAT Remediation Project. Cold Testing was completed in May 1997 and the equipment relocated to Tank W-3 in the ORNL North Tank Farm.

The first deployment of Houdini in Tank W-3 occurred on June 25, 1997. Operations in Tank W-3 continued until mid September when Tank W-3 waste removal and associated characterization activities were completed to the satisfaction of the Environmental Protection Agency and the Tennessee Department of Oversight Environment and Conservation. More than 14,000 gallons of sludge and supernate were removed from Tank W-3 and transferred to a consolidation tank for future treatment and disposal. Houdini was used for a variety of tasks in addition to deployment of the confined sluicing end-effector for waste retrieval operations. Core samples were obtained of the gunite walls along with a variety of other solid, liquid and slurry samples. Analysis of the core samples showed that more than 90% of the remaining radioactive material in the walls is within about 1/8 inch of the surface. A large amount of debris was removed from the tank, including pipes, conduit, cables, rope, tape, tools, gloves, and plastic bags that had been dumped or dropped in the tank over the past 50 years. Houdini operated a hydraulic shear to remove and down size a bundle of pipes, cables and conduit. The combined mobility and manipulation capabilities of the Houdini system make it a highly versatile utility vehicle for use in hazardous environments.